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RESEARCH MEMORANDUM

SOME RESULTS OF FLIGHT TESTING OF SKI-EQUIPPED AIRCRAFT
AT THE NAVAL AIR TEST CENTER

By Preston E. Beck

Naval Air Test Center

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON

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RESEARCH MEMORANDUM

SOME RESULTS OF FLIGHT TESTING OF SKI-EQUIPPED AIRCRAFT

AT THE NAVAL AIR TEST CENTER

By Preston E. Beck¹

SUMMARY

This report covers in part the results of flight testing of four different ski-equipped airplanes at the Naval Air Test Center. Two types of skis were investigated, namely, (1) hydro-skis designed to operate under or on the water surface and (2) general-purpose skis designed to operate on a variety of surfaces but not under water.


Recorded herein are a portion of the results of the tests on the general practicability of the ski installations and their hydrodynamic characteristics. Of particular interest was the proof of results indicated by model tests conducted by the National Advisory Committee for Aeronautics of the superior handling characteristics in rough water of the hydro-ski-equipped airplane as compared with conventional hull-type seaplanes.

INTRODUCTION

The rapid increase in the size and weight of military airplanes has taxed the capacity of aircraft carriers and airfields to support flight operations. This has led many designers to the consideration of using the extensive ocean areas and adjacent beaches as airfields. Although the space is available, the ever changing shape of such surfaces has presented formidable problems. There has resulted, therefore, an investigation by personnel of the United States Navy, associated civilian agencies, and the NACA of the possibility of utilizing ski-equipped aircraft to operate in such areas. The first step in the program was extensive model tests by the NACA. A portion of the data obtained from these tests is given in references 1 through 6.

This report presents in part the results of the second step in the program consisting of full-scale flight testing of ski-equipped JRF-5,

¹Lieutenant Commander, United States Navy.



SNJ-5C, and OE-1 airplanes. The purposes of these tests conducted at the Naval Air Test Center were to evaluate the hydrodynamic characteristics, determine the general practicability of ski installations, and obtain data on the loads being sustained by the landing gear. With the exception of the OE-1 airplane, all the ski-equipped airplanes were "test beds" for development work and were not intended for general use by the United States Navy.

The tests were of a quantitative as well as qualitative nature. Detailed information regarding the special instrumentation and piloting techniques is not given herein but may be obtained from the Bureau of Aeronautics, Navy Department, Washington, D. C.

This report has been made available to the NACA for publication because of its general interest.

DESCRIPTION OF TEST VEHICLES

Two types of skis were tested. The first was the true hydro-ski which was capable of operating under water or on the water surface. The second type of ski had a flat bottom and was designed to operate on a variety of surfaces, such as water, mud, sand, snow, grass fields, and paved runways. The latter type of ski was not capable of under-water operation and operation on the water had to be restricted to speeds above that which allowed the skis to plane on the water surface. No static flotation was provided with the airplanes having this type of general-purpose ski.

JRF-5 Airplane With Single Hydro-Ski

Figure 1 shows a model JRF-5 airplane with a single hydro-ski mounted below its keel. Water loads were transmitted through a strut within a vertical fairing at the airplane plane of symmetry. The vertical fairing covered the strut to reduce the hydrodynamic drag. The installation had interchangeable rigid and oleo shock struts. With the oleo shock strut installed, a one-piece fairing over the rigid strut was replaced by two telescoping sections (fig. 2). The hydro-ski had a fixed angle of incidence and the trim was varied by rotating the entire airplane.

A special feature was a hydrodynamic trim flap located at the transom directly below the rudder of the airplane. The angle of opening of this flap in the longitudinal plane could be set at 0° , 12.5° , or 27° . A brief evaluation was also made of outriggers mounted below each wing-tip float.

JRF-5 Airplane With Twin Hydro-Skis

Figure 3 shows a model JRF-5 airplane equipped with twin hydro-skis. The oleo shock struts which attached the hydro-skis to the airplane were inclined 25° from the vertical as shown in figure 3. This geometric position resulted in bending moments that restricted oleo action because of binding between the inner and outer cylinders. Therefore, the oleo shock struts did not properly damp the loads being transmitted to the hull of the airplane. Oleo air pressures in excess of 250 pounds per square inch were required in order to insure positive strut extension under decreasing loads.

Figure 4 shows the spray dams which were attached to the bows of the basic hydro-skis to improve the main spray characteristics.

The test airplane featured self-contained beaching gear consisting of a wheel in each hydro-ski along with the tail-wheel assembly of the original JRF-5 landing gear. In order to permit taxiing operations up and down a seaplane ramp the hydro-skis were equipped with a mechanism which allowed them to rotate in the longitudinal plane.

Ski Installation on SNJ-5C Airplane

Figure 5 shows a model SNJ-5C airplane equipped with flat-bottom skis having a wheel assembly. The pilot could control the trim of these skis in that they could be fixed 14° nose down (relative to the airplane thrust line) or 4° nose up. The pilot also had a control that would permit the skis to seek their own trim individually (free trim). Two-position hydraulically actuated flaps were attached to both sides of each ski. These ski flaps, when lowered to the horizontal position, increased the area of each ski approximately 45 percent.

Ski Installation on OE-1 Airplane

Figure 6 shows an OE-1 airplane equipped with flat-bottom skis attached to the struts of the main landing gear. The basic OE-1 landing gear was not modified; the original wheel assembly was used in conjunction with the skis to permit operations on hard surfaces. The trim of the skis was controlled by the pilot in the same manner as was the trim of the SNJ-5C skis.

This was the first ski-equipped airplane tested to determine the suitability of the gear for service use. This particular ski assembly was unique in that it could be easily and quickly removed from any particular airplane and installed on another of the same type. After

removal of the assembly, the airplane was in its original configuration and could continue to operate off prepared surfaces.

RESULTS AND DISCUSSION

JRF-5 Airplane With Single Hydro-Ski

Take-off performance.- Table I and figure 7 present representative data obtained during take-offs of the JRF-5 airplane with a single hydro-ski where the parameters were variation in gross weight and the interchangeable rigid- or oleo-shock-strut configuration. Figure 8 shows the change in unporting and take-off performance with an increase in gross weight from about 8,300 to 9,100 pounds. The maximum gross weight of the unmodified airplane for water operations was 8,000 pounds. (Transition of the hydro-ski from operation under water to planing on the surface is known as unporting.) The effect of increase in gross weight on handling characteristics was similar to that experienced in conventional seaplanes.

Handling and stability characteristics in smooth water.- Movement of the center-of-gravity position from 20.0 to 26.5 percent of the mean aerodynamic chord did not cause any change in handling characteristics that are not found with conventional seaplanes. At the forward center-of-gravity position there was heavier spray through the propeller arcs during unporting than at the aft position. This was due to the slightly lower trim angles for the forward center-of-gravity position.

Handling characteristics during unporting improved when the hydrodynamic trim flap was opened to the 12.5° position. The records did not show substantial changes in the elevator positions, so it appeared that the improvement was due to a reduction in elevator control forces.

The critical point of operation of the test airplane was in the unporting of the hydro-ski during take-offs. There was sufficient engine power to provide positive acceleration and sufficient elevator control at all times. Directional control was excellent except for the conditions noted below. In some cases unporting could not be completed, and this was the result of insufficient lateral control. Further, the unporting was accompanied by a great deal of spray that resulted in a decrease in the available power. When the pilot was unable to prevent a wing float from contacting the water during unporting, the drag increase was sufficient to stop longitudinal acceleration and to cause the pilot to lose directional control. The airplane then moved at a constant velocity in a steady turn at a high angle of trim (hydro-ski partially unported) with the afterbody of the airplane in contact with the water.

This lateral-control deficiency was evident regardless of wind direction but was so critical that crosswind operations were impractical.

When the planing velocity decreased as in landings, the pitching moment of the hydro-ski reversed from nose down to nose up and the angle of trim of the airplane increased from 3° to 6° to approximately 15° to 20° . Submergence of the hydro-ski was rapid and, as the hull contacted the water, the airplane usually yawed abruptly in either direction.

The approximate trim limits of hydrodynamic stability are shown in figure 9. The unporting range for this hydro-ski airplane configuration lies almost entirely on the low-speed lower limit stability boundary. The upper limit of stability was not investigated because of the exceptionally high trim angles that would be encountered.

During the hydro-ski—submerged portion of the take-off run, the pilot reported the occasional development of an objectionable but controllable divergent oscillation in the longitudinal plane. This oscillation indicated inherent longitudinal instability of the hydro-ski when running submerged. Further, when the hydro-ski was running submerged, a violent uncontrollable hooking in either direction was often encountered. Since the afterbody of the main hull was usually in contact with the water during this portion of the run, it is believed that this hooking was due to the flow characteristics in this region. This could not be checked visually because spray obscured the flow.

Oleo shock strut and outriggers.— The oleo shock strut was larger than the rigid strut. The correspondingly larger strut fairing resulted in a substantial decrease in the acceleration that could be obtained during unporting. The result was a deterioration of the lateral control characteristics during unporting.

Pilots noticed a decided difference between the two types of struts when planing through waves of short wave length. As the hydro-ski cut each wave, there was a momentary change in the loading and in the wetted area. At higher velocities this factor took on the aspect of a vibration. The oleo shock strut was capable of removing most of the vibration. However, at the velocities involved (80 knots indicated airspeed or less) the vibration never became annoying to the pilots when the fixed main strut was installed in the airplane.

Outriggers were installed below the wing-tip floats during the tests to evaluate their usefulness. The desirable procedure was to keep the outrigger hydro-skis on the surface because the drag was substantially lower than when they were submerged. Unporting was possible in more adverse wind conditions when this procedure was used than when the outriggers were removed. However, the increase in drag and weight due to the outriggers discouraged their use.

Rough-water operation.— The rough-water handling characteristics of the single hydro-ski—equipped airplane with the oleo-shock-strut configuration were evaluated by conducting landings and take-offs in the Chesapeake Bay. All runs were made into the wind and waves. The water becomes very rough in this area during high winds, but the wave lengths are short, in contrast with those in the open sea. One test was made in an 18- to 20-knot north wind off the lee side of the western shore.

The waves were estimated to be 2 to $2\frac{1}{2}$ feet high with about 30 feet from crest to crest. Another test was made in a 20-knot south wind where the fetch was about 90 nautical miles. Waves were estimated to be $3\frac{1}{2}$ feet high with an occasional 5-foot maximum and 50 feet from crest to crest. These estimates were made by comparing the wave dimensions with those of the crash boat and the test airplane. The water was sufficiently rough during the later mentioned test that the crash boat (50 feet long) suffered minor damage from the waves and the pilot reported that he was unable to see the horizon when the airplane was in the trough of a wave.

Landings in waves of this nature were surprisingly easy. A conventional-type seaplane of this size would have been bouncing, pitching, and undergoing severe loads during the numerous impacts. In the test vehicle this bouncing and pitching could be controlled by use of the elevators. As was indicated by model tests, the hydro-ski has considerably less tendency to try to follow the wave contour than conventional seaplane hulls, which results in improved handling characteristics.

Rough-water take-offs were complicated by the heavy spray before unporting. As power was applied, heavy spray would break over the bow of the main hull of the seaplane, pass through the propeller arcs, and strike the control surfaces. This resulted in substantial losses in propeller speed and thrust and in high control forces. When the water loads on the two propellers were substantially unbalanced, the asymmetric thrust caused the pilot to lose directional control as the airplane was brought up to the high trim angle needed to unport the hydro-ski. Once unporting was accomplished, the take-off run could be made without any further difficulty. It was very noticeable to the pilot that nearly constant trim could be maintained during the take-off run after unporting and the airplane was not prematurely thrown into the air by impact with a wave. This is in contrast with conventional seaplane rough-water operation.

JRF-5 Airplane With Twin Hydro-Skis

Spray characteristics.— As the bows of the twin hydro-skis on the JRF-5 airplane penetrated the surface of the water (emergence or

submergence), heavy spray was projected up and forward and the airplane then traveled into this curtain of water. Further, the spray from the chines of the hydro-skis traveled up vertically and passed through the entire propeller disk area and covered the canopy with water. This heavy spray over the aircraft resulted in very poor take-off performance and severe erosion of the propeller blades.

Installation of spray dams on each hydro-ski around the bow and along the outboard sides to station 35 improved the characteristics. The spray envelope was substantially reduced by this modification and there was a noticeable improvement in the acceleration during unporting. Figure 10 is a sequence of still photographs taken during a take-off that shows the spray characteristics with the spray dams installed on the hydro-skis. The exceptionally heavy spray, shown in figure 10(c), resulted when the hydro-skis prematurely unported at a low trim angle. Figure 10(e) shows the spray during the intended unporting of the hydro-skis when the airplane was deliberately brought to a high degree of trim.

Hydrodynamic stability and control characteristics.- A qualitative investigation was made to determine the limits of the hydrodynamic stable range. No instability was noted throughout the planing portion of the take-off. Trim angles for planing were varied from 2° to 10° nose up. The 2° trim angle is the lowest possible for comfortable planing and was set as an arbitrary limit because nothing was known about the diving characteristics of these hydro-skis. The maximum trim angle was established by the length of the hydro-ski struts at about 10° because at this angle the sternpost of the main hull was in contact with the water. At a gross weight of 8,600 pounds (center of gravity at 16.8 percent of the mean aerodynamic chord), take-offs were made with full up elevator without encountering unstable oscillations.

The condition of the hydro-skis unporting with the aircraft at a very high trim angle was the most critical point during a take-off. The spray characteristics were such that the rate at which the trim angle was decreased had to be very carefully judged by the pilot. In figure 11 the time history of trim is given for five take-offs. The longitudinal oscillation following the unporting shown on some of the trim records was not porpoising due to instability but was introduced by the pilot as he sought to lower the nose as rapidly as possible and occasionally had to increase the trim again to raise the propeller arcs relative to the spray envelope. This technique undoubtedly obscured the lower limit of hydrodynamic stability if such a limit existed.

Qualitative tests showed that the twin-hydro-ski installation exhibited poor longitudinal control characteristics during the take-off run prior to unporting (center-of-gravity position varied from 15.4 to 21.4 percent mean aerodynamic chord). The poor longitudinal control characteristics were manifested by the fact that the pilot was often

unable to prevent preemergence of the hydro-skis before conditions were suitable for a successful unporting. The low unporting velocity of this particular twin-hydro-ski configuration was accompanied by so much adverse spray that for extensive operations it had to be avoided even though there was sufficient lateral control. Unporting at a higher velocity moved the spray envelope aft, decreasing the amount of spray through the propeller arcs.

Take-off performance.- Figure 12 is a plot of the effect of variation in take-off time with gross weight. It is suspected that the performance would deteriorate very rapidly at gross weights above 9,100 pounds because of the effects of spray. Although there was only a small variation in take-off performance over the range of gross weights tested, the higher weights had a decided effect on the piloting technique. As the weight was increased, the increased wetted length of the hydro-skis affected the spray characteristics unfavorably and it was necessary to hold the aircraft at relatively high trim angles just after unporting in order to prevent an increase in the amount of heavy spray through the propeller arcs. This high trim angle resulted in higher over-all drag. There was, therefore, relatively poor acceleration in a range where acceleration would be excellent if the trim could be immediately decreased to the optimum planing attitude (3° to 6°).

Landing characteristics.- Landings were not accompanied by any unusual control problems. Handling characteristics are superior to those of conventional hull-type seaplanes. If drifting was not completely eliminated just prior to contact with the water, the hydro-skis planed in a yawed condition (yaw angles above 2° have not been investigated in this speed range) with no tendency to water-loop. When landing downwind, conventional seaplanes have a tendency to go to very low trim angles and care must be taken not to allow the curved portion of the forebody to enter the water at high speeds, as this results in a strong destabilizing moment (pitch down). The hydro-skis eliminate this factor because of the absence of a large curved keel near the bow.

Beaching wheels and variable-trim mechanism.- The utilization of wheels within the hydro-skis to allow unassisted beaching and launching is vastly superior to the use of beaching gear. The test airplane could be taxied down the seaplane ramp as soon as the engines were warm and take-off could be commenced as soon as the water was reached. For military operations, this is preferable to the standard seaplane launching operation as now practiced.

Difficulty was experienced with the mechanism associated with rotation of the hydro-skis in the longitudinal plane when beaching or launching. The mechanism was contained within the hydro-skis and was repeatedly immersed in salt water. Corrosion became a problem and extensive maintenance was required to keep the moving parts functioning.

Ski Installation on SNJ-5C Airplane

The SNJ-5C airplane was operated on paved runways, dry grass fields, a soft sand beach, a seaplane ramp (12 to 1 slope), and also water under varied wind and surface conditions. These were all suitable surfaces except for the beach and there the wheel and ski drag was so high that the available engine power would not move the airplane.

Operation from a ramp.- With the skis in the free-to-trim condition the airplane could be stopped on a hard surface such as a seaplane ramp. For take-off from a seaplane ramp a short run to the water was sufficient to allow the airplane to reach planing velocity. When sufficient velocity was obtained to plane with ease, the skis were fixed in the 4° nose-up position and the ski flaps raised. This change in configuration would normally result in a reduction in drag and permit take-off in a shorter length of time. It was possible to raise the ski flaps too soon. When this was done, the wetted ski length, and consequently the drag, could be increased to the point where the drag exceeded the thrust.

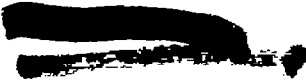
Operation in choppy water.- The airplane was close to the water during taxiing operations because of the short distance between the skis and the fuselage. When the waves were over 12 inches in height, the crests of the waves struck the wing flaps and subjected them to severe water loads. Crosswind taxiing in waves over 6 inches high was not practical because the skis rode the crests and troughs of the waves alternately, introducing rolling of the airplane that brought the wing tips uncomfortably close to the water.

Ski Installation on OE-1 Airplane

Operation from prepared surfaces.- Operation of the OE-1 airplane with the ski installation from a paved surface was similar to that of the basic airplane. The ski installation did not place any limitations on the airplane with regard to operating off a hard surface.

Operation from open fields and swamp areas.- A grass field, wet or dry, was found to be an excellent surface for ski operations. The skis were allowed to trim free so that they could rotate while passing over the uneven terrain and in tall grass. Large obstructions and sharply sloped depressions obviously were avoided.

Take-offs and landings were made in mud and muck of several consistencies. Mud containing a high percentage of sticky clay was found to be unsuitable. As the wheels rotated, the mud stuck to the tires and filled the space between the wheel and ski. The mud accumulation could stop wheel rotation. During taxiing tests in the mud, straw and brush were found to be effective in reducing the sticking tendency.



[REDACTED]

Removal of the wheel spray shields from the skis aided operations in mud areas because the resultant increase in wheel-ski clearance enabled the mud-covered wheel to rotate more freely. Operations in muck as found in swamp areas were more successful, for the drag was lower and the muck did not stick to the wheels.

Operation in water-beach areas.- Approximately 100 landings and take-offs were made utilizing water-beach areas as shown in figure 13. The beaches were composed of sand. Relatively firm sand such as that uncovered by an ebbing tide and sand with a high gravel content were generally suitable for operations. It was difficult if not impossible to taxi unassisted where there was surf or loose wind-blown sand above the high-water mark. Forward movement of the airplane in this type of sand often resulted in a mound of increasing size being built up ahead of the flat ski bow. After only a few feet of travel, the mound often became large enough to stop forward motion completely. A relatively fast taxiing speed usually enabled the skis to pass over and through loose sand to firmer sand further inland. To free the airplane from loose sand, the assistance of three men pushing against the wing struts was required. It is believed that a ski bow such as that used on speed boats would improve the taxiing characteristics on sand surfaces. Such a bow would tend to trim-up and push the sand to one side rather than pile it ahead of the ski.

At the edge of the water small-radius 180° turns were successfully made, enabling the airplane to operate from small beach areas. These turns were made with the tail of the airplane over the water in order to keep clear of obstructions above the high-water mark.

The transition from the beach to the water was the most critical point in the operation. When waves were breaking on the beach, the transition became more critical. Successful take-offs were made into a 12-inch surf. The above condition was not limiting; but, since there was deceleration upon initial contact with the surf as heavy spray broke over the airplane, good initial airplane acceleration and a relatively high ground speed were required before turning into the water.

Operation on snow.- Operations were conducted on paved runways and grass fields covered with freshly fallen light dry snow up to 8 inches deep. Acceleration was poor in light dry snow because the skis sank until the wheels contacted a hard surface. It was possible to taxi across snow drifts over 2 feet high which were left by a snow plow. To do this a run of at least an airplane length was needed to obtain good initial acceleration before contacting the bank.

Operations were also conducted on paved runways and grass fields covered with wet (melting) snow up to 10 inches deep. Take-off performance was good in wet snow up to about 6 inches deep. The wet snow accumulated on top of the skis and piled as high as the top of the wheels.

[REDACTED]

Operation in choppy water.- The tests had to be curtailed before the full capabilities of the airplane in rough water could be determined. It was noted that waves 6 inches or more in height would start the landing-gear assembly vibrating up and down at its natural frequency. The steel-spring landing-gear strut was effective in reducing the loads being transmitted to the airplane, but no provision was made for damping and waves are an excellent forcing function. In waves the vibration was accompanied by adverse spray and it was surmised that the limit would soon be reached in waves over 1 foot high.

CONCLUSIONS

Flight testing of JRF-5, SNJ-5C, and OE-1 airplanes equipped with skis yielded a number of conclusions, as listed below:

JRF-5 Airplane With Single Hydro-Ski

1. Handling characteristics were satisfactory in the center-of-gravity range tested (20.0 to 26.5 percent mean aerodynamic chord) and were similar to those encountered in a conventional airplane.
2. Increasing the gross weight decreased the take-off performance. The hydro-ski made it possible to operate the test vehicle off the water at substantially higher gross weights than were possible with the standard configuration.
3. The most detrimental factors discovered under all conditions tested were marginal lateral control and heavy spray through the unporting range during take-off.
4. The hydro-ski exhibited exceptionally good rough-water characteristics. The pilots conducted landings and take-offs directly into the oncoming seas without subjecting the airplane to severe loads. It was particularly noted that the ski-equipped airplane had less tendency to bounce into the air after impact with a wave than conventional seaplanes.

JRF-5 Airplane With Twin Hydro-Skis

1. The spray characteristics were unsatisfactory. This resulted in inferior take-off performance as compared with other ski-equipped airplanes which were evaluated at the Naval Air Test Center.

2. A qualitative investigation did not disclose the presence of an upper or lower limit of hydrodynamic stability. Pilot technique may have obscured the presence of a lower limit.

3. Handling characteristics were satisfactory except for the region prior to unporting in the center-of-gravity range tested (15.4 to 21.4 percent mean aerodynamic chord) and were similar to those encountered with conventional seaplanes.

4. The elimination of beaching gear by incorporation of wheels within the hydro-skis is very desirable.

SNJ-5C and OE-1 Airplanes With Skis

1. The ski installations increased the versatility of the airplanes by permitting operations from a variety of surfaces including established airfields. There were some limitations, however, in operation on loose sand, mud, snow, and rough water, particularly with the SNJ-5C airplane.

Naval Air Test Center,
Patuxent River, Md., July 9, 1954.

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TABLE I.- TAKE-OFF RECORDS FOR JNF-5 AIRPLANE WITH SINGLE HYDRO-SKI

(a) Rigid-strut configuration

| Center-of-gravity position, percent M.A.C. | Wind velocity, knots | Hydrodynamic-trim-flap opening, deg | Unporting | | Take-off | | | Maximum pitching moment, ^a ft-lb | |
|--|----------------------|-------------------------------------|--------------------------------|-----------|------------------------|-----------|---------------------------|---|-----------|
| | | | Maximum trim, ^b deg | Time, sec | Trim, ^b deg | Time, sec | Indicated airspeed, knots | Nose up | Nose down |
| Take-off gross weight, 8,540 lb | | | | | | | | | |
| 23.6 | 4 | 12.5 | 18.9 | 6.0 | 11.2 | 19.0 | 65 | 10,800 | — |
| 23.6 | 6 | 0 | 18.8 | 9.0 | 9.3 | 19.5 | 65 | 12,300 | 11,850 |
| 23.6 | 6-8 | 0 | 18.8 | 6.0 | 8.3 | 19.0 | 61 | 11,185 | 11,775 |
| 23.6 | 2 | 27.0 | 17.0 | 10.0 | 10.6 | 24.0 | 60 | 7,025 | — |
| 23.6 | 2 | 27.0 | 17.8 | 10.0 | 10.4 | 26.0 | 60.5 | — | 7,100 |
| 23.6 | 2 | 27.0 | 18.1 | 10.0 | 10.2 | 24.0 | 60 | 7,100 | — |
| 20.0 | 5 | 0 | 18.3 | 8.8 | 10.1 | 19.5 | 58.5 | 9,875 | 10,975 |
| 20.0 | 5 | 0 | 16.2 | 8.0 | 9.7 | 19.0 | 55.5 | 13,975 | 14,800 |
| 20.0 | 5 | 12.5 | 17.5 | 9.5 | 8.1 | 20.5 | 60 | 8,200 | 14,000 |
| 20.0 | 5 | 12.5 | 17.9 | 9.7 | 9.8 | 20.7 | 58.5 | 10,600 | 13,400 |
| 23.6 | 8-10 | 0 | 19.4 | 8.0 | 11.6 | 18.0 | 60 | 12,725 | 12,725 |
| 23.6 | 8-10 | 0 | 17.2 | 7.0 | 12.0 | 17.0 | 58 | 7,175 | 12,725 |
| 23.6 | 5 | 12.5 | — | 7.0 | — | 19.5 | 60.5 | 9,600 | 10,450 |
| 23.6 | 2 | 27.0 | 18.3 | 9.5 | 10.4 | 23.5 | 65.5 | — | 6,660 |
| 26.5 | 5 | 27.0 | 20.7 | 9.0 | 11.6 | 18.0 | 62 | 6,800 | 11,725 |
| 20.0 | 6 | 27.0 | 17.5 | 11.0 | 11.4 | 21.0 | 61.5 | 8,350 | 11,000 |
| 20.0 | 6 | 27.0 | 15.6 | 10.0 | 10.3 | 19.5 | 63 | 9,075 | 11,025 |
| 20.0 | 5 | 0 | 15.0 | 8.5 | 8.5 | 22.0 | 65 | 13,000 | 12,500 |
| 23.6 | 6 | 0 | 20.0 | 7.6 | 10.5 | 18.5 | 60 | 18,000 | 12,500 |
| 26.5 | 8 | 0 | 19.0 | 7.1 | 10.5 | 18.1 | 58 | 13,000 | 10,000 |
| Take-off gross weight, 8,540 lb | | | | | | | | | |
| 22.0 | Calm | 12.5 | 17.8 | 9.5 | 11.2 | 24.0 | 56 | 8,050 | 6,775 |
| 22.0 | Calm | 12.5 | 20.7 | 9.5 | 11.0 | 19.0 | 60.5 | 7,325 | — |
| Take-off gross weight, 8,740 lb | | | | | | | | | |
| 22.0 | Calm | 12.5 | 14.6 | 11.0 | 7.8 | 26.0 | 60.5 | 7,400 | 7,175 |
| 22.0 | Calm | 12.5 | 15.2 | 10.2 | 6.7 | 22.0 | 62.5 | 7,175 | 6,700 |
| Take-off gross weight, 9,140 lb | | | | | | | | | |
| 22.0 | 6 | 12.5 | 15.4 | 12.0 | 9.8 | 23.5 | 61.0 | 9,000 | 8,200 |
| 22.0 | 9 | 12.5 | 18.0 | 11.0 | 12.0 | 25.0 | 63.0 | 8,575 | 8,700 |

^aMoments are about point of attachment of main vertical strut to hydro-ski. They were determined by strain-gage measurements of axial forces in rigger strut which held hydro-ski at a fixed angle of incidence.

^bTrim of keel of hydro-ski relative to horizon (nose up).

TABLE I.- TAKE-OFF RECORDS FOR JRF-5 AIRPLANE WITH SINGLE HYDRO-SKI - Concluded

(b) Oleo-shock-strut configuration

| Gross weight, lb | Center-of-gravity position, percent M.A.C. | Wind velocity, knots | Hydrodynamic-trim-flap opening, deg | Outriggers (on or off) | Oleo-strut air pressure, lb/sq in. | Time, sec | | Take-off (indicated airspeed), knots |
|--|--|--------------------------------|-------------------------------------|---|------------------------------------|--|-------------|--------------------------------------|
| | | | | | | To unport | To take off | |
| 8,500 | 23.6 | 13 | 0 | Off | Locked up | 9.4 | 17.8 | 59.0 |
| 8,500 | 23.6 | 13 | 0 | Off | Locked up | 10.1 | 16.3 | 61.0 |
| 8,500 | 23.6 | 12 | 0 | Off | Locked up | 9.7 | 16.1 | 57.0 |
| 8,500 | 23.6 | 10 | 0 | Off | 400 | 17.7 | 29.2 | 61.0 |
| 8,500 | 23.6 | 7 | 0 | Off | 200 | 16.5 | — | — |
| 8,500 | 23.6 | 10 | 0 | Off | 600 | 14.7 | 24.6 | 58.5 |
| 8,500 | 23.6 | 10 | 0 | Off | 600 | 14.4 | 25.1 | 62.0 |
| 8,500 | 23.6 | 12 | 0 | Off | 400 | 15.0 | 25.3 | 61.0 |
| 8,500 | 23.6 | 12 | 0 | Off | 400 | 11.8 | 20.8 | 62.5 |
| 8,650 | 23.4 | 3 | 12.5 | On | 400 | 16.0 | 28.0 | 56.0 |
| 8,650 | 23.4 | 3 | 12.5 | On | 400 | 21.0 | 36.5 | 61.0 |
| Longitudinal acceleration, ft/sec ² | | Maximum trim, ^b deg | | Maximum pitching moment, ^a ft-lb | | Maximum angular acceleration, radians/sec ² | | |
| During unporting | At take-off | During unporting | At take-off | Nose up | Nose down | Nose up | Nose down | |
| 10.6 | 10.9 | 14.9 | 9.4 | 13,200 | 9,300 | 0.75 | 0.25 | |
| 12.2 | 10.0 | 11.2 | 5.5 | 12,000 | 8,400 | .90 | .90 | |
| 12.2 | 11.3 | 12.8 | 6.6 | 6,900 | 9,150 | .35 | 1.05 | |
| 12.8 | 11.5 | 18.5 | 9.7 | 13,200 | 7,750 | .75 | .45 | |
| 11.1 | 11.5 | 18.3 | 9.5 | 5,770 | 4,250 | .80 | .45 | |
| 10.6 | 11.1 | 18.3 | 10.4 | 11,100 | 7,900 | .75 | .51 | |
| 13.7 | 10.2 | 18.7 | 9.4 | 6,100 | 8,800 | .25 | .90 | |
| 9.8 | 10.6 | 19.6 | 10.4 | 11,250 | 8,200 | 1.05 | .90 | |
| 11.9 | 10.6 | 18.1 | 10.9 | 5,325 | 9,150 | .65 | .75 | |
| 10.2 | 10.0 | 16.6 | 8.3 | 5,625 | 5,800 | .05 | .70 | |
| 10.0 | 9.6 | 17.5 | 9.1 | 6,700 | 7,900 | .57 | 1.17 | |

^aMoments are about point of attachment of main vertical strut to hydro-ski. They were determined by strain-gage measurements of axial forces in rigger strut which held hydro-ski at a fixed angle of incidence.

^bTrim of keel of hydro-ski relative to horizon (nose up).

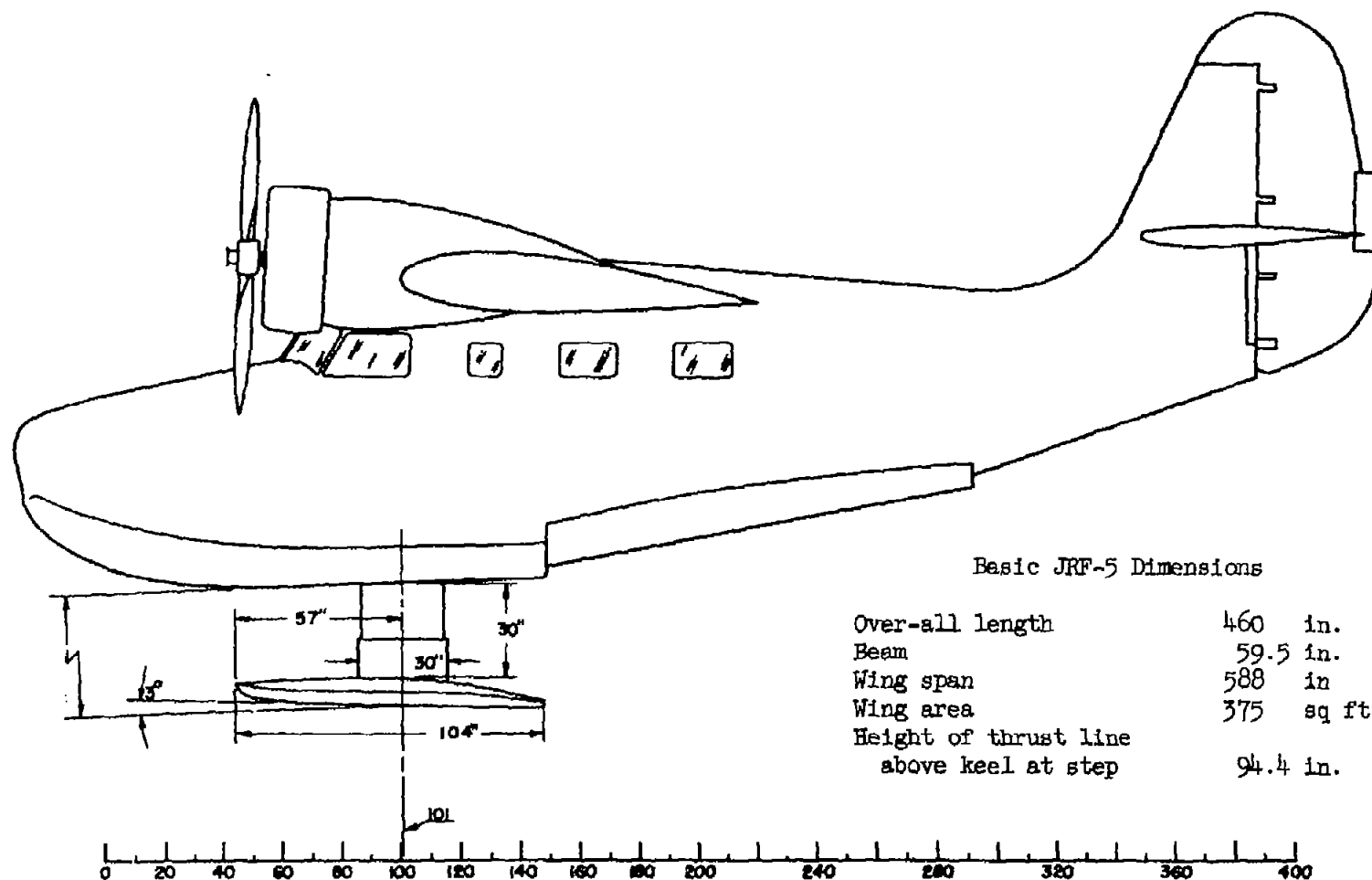
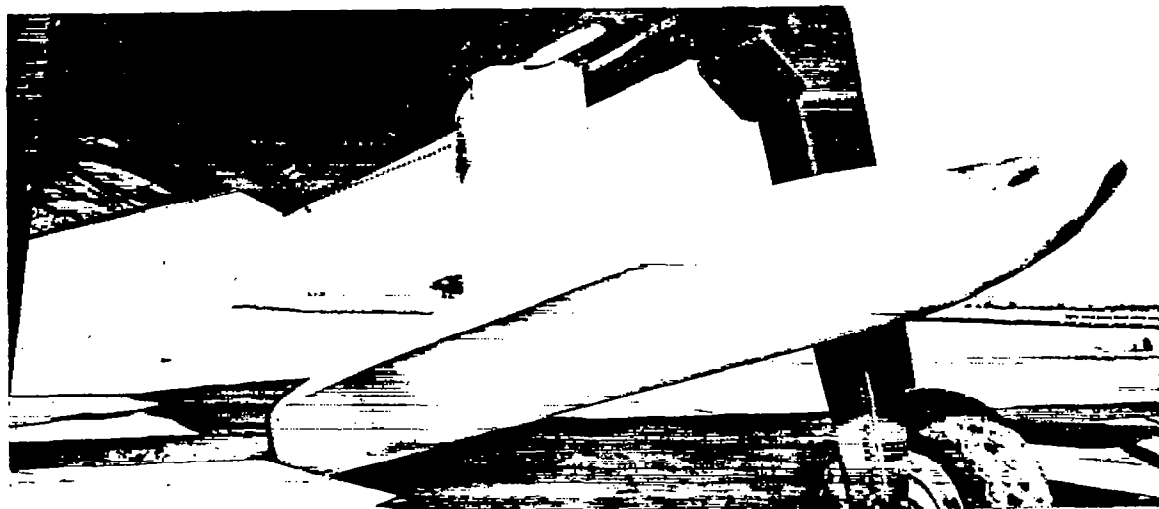
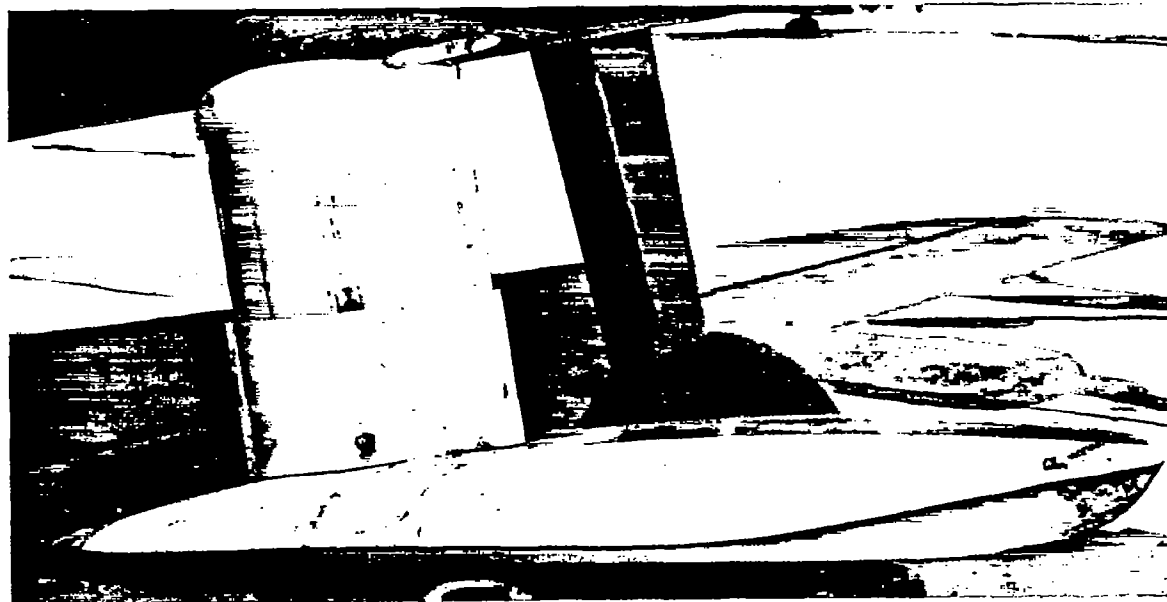


Figure 1.- Single hydro-ski on a JRF-5 airplane (oleo-shock-strut installation).



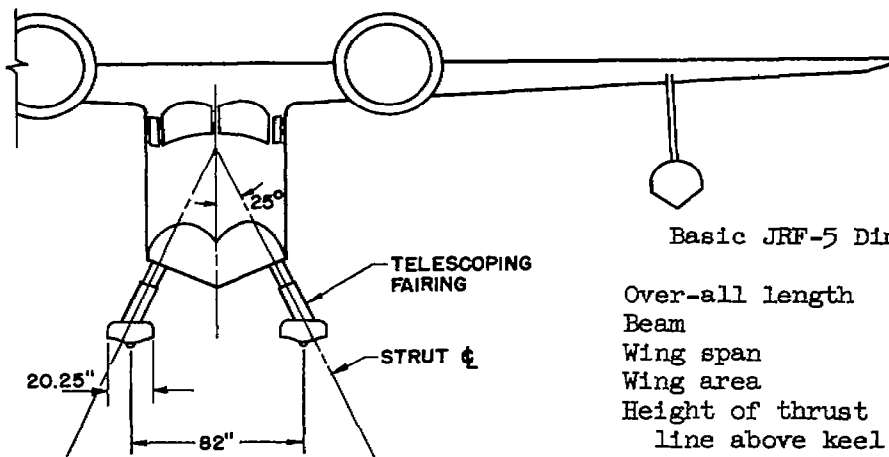
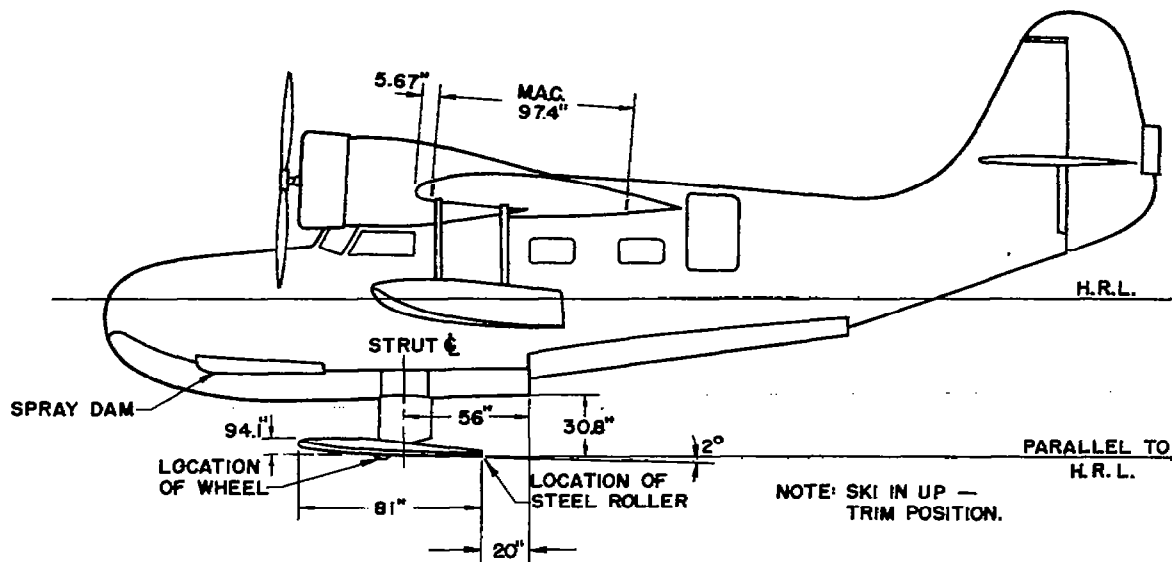
(a) Rigid-strut configuration.



(b) Oleo-shock-strut configuration.

L-87553

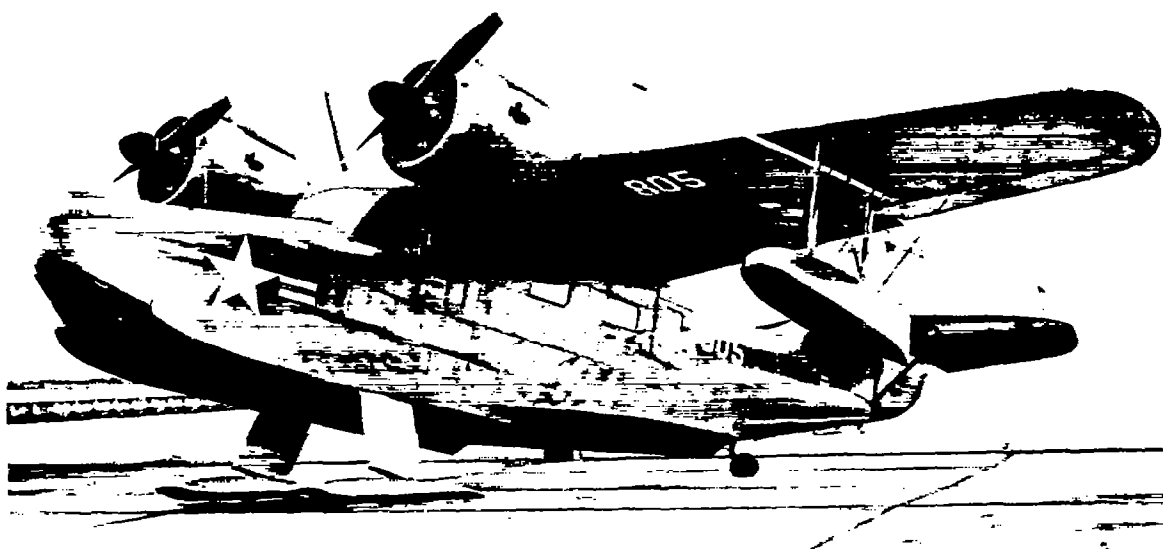
Figure 2.- Single hydro-ski installation on a JRF-5 airplane.



Basic JRF-5 Dimensions

| | |
|--|-----------|
| Over-all length | 460 in. |
| Beam | 595 in. |
| Wing span | 588 in. |
| Wing area | 375 sq ft |
| Height of thrust line above keel at step | 94.4 in. |

Figure 3.- General arrangement of twin-hydro-ski installation on a JRF-5 airplane (oleo shock struts fully extended).

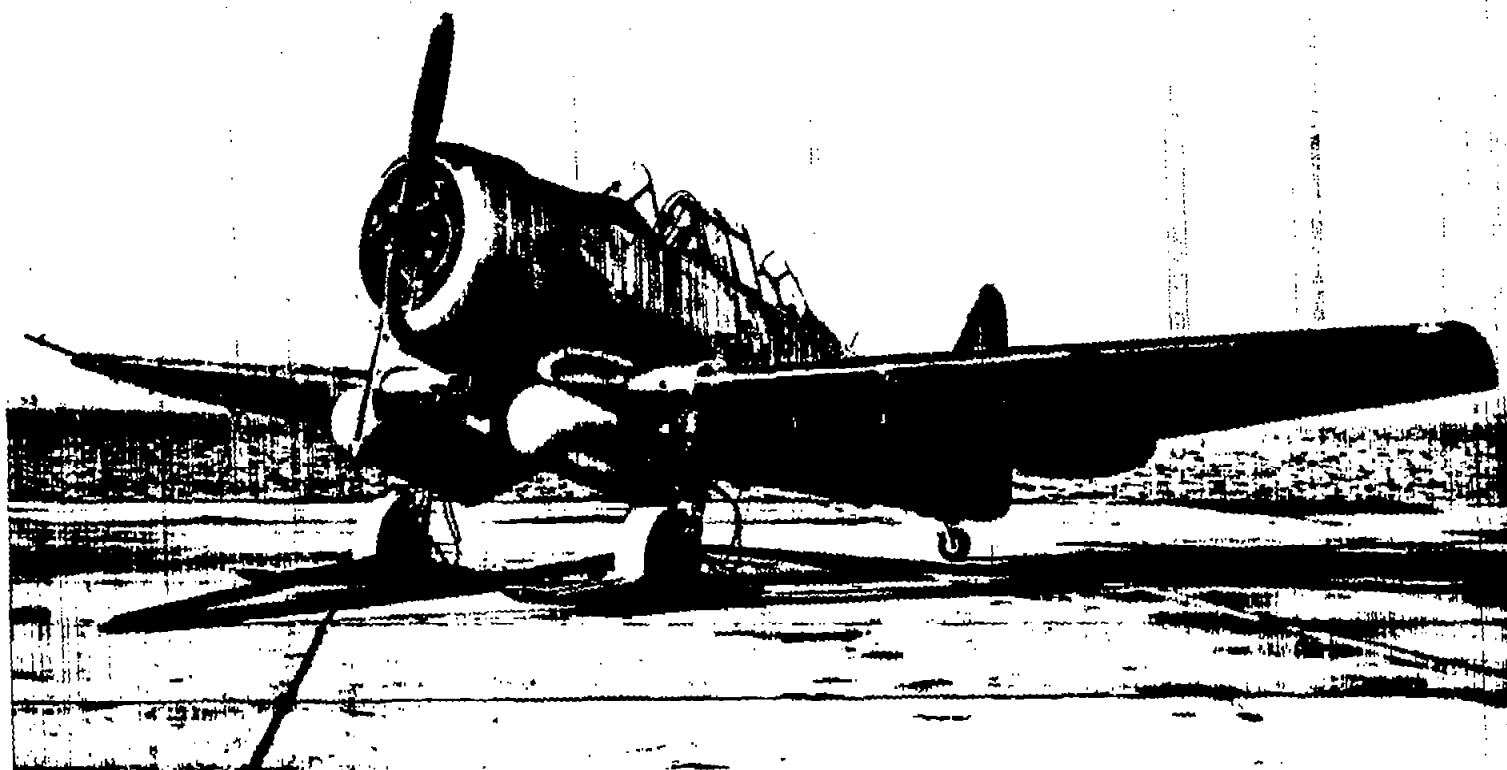


(a) Three-quarter front view of airplane.



(b) Close-up view of skis showing spray dams. L-87554

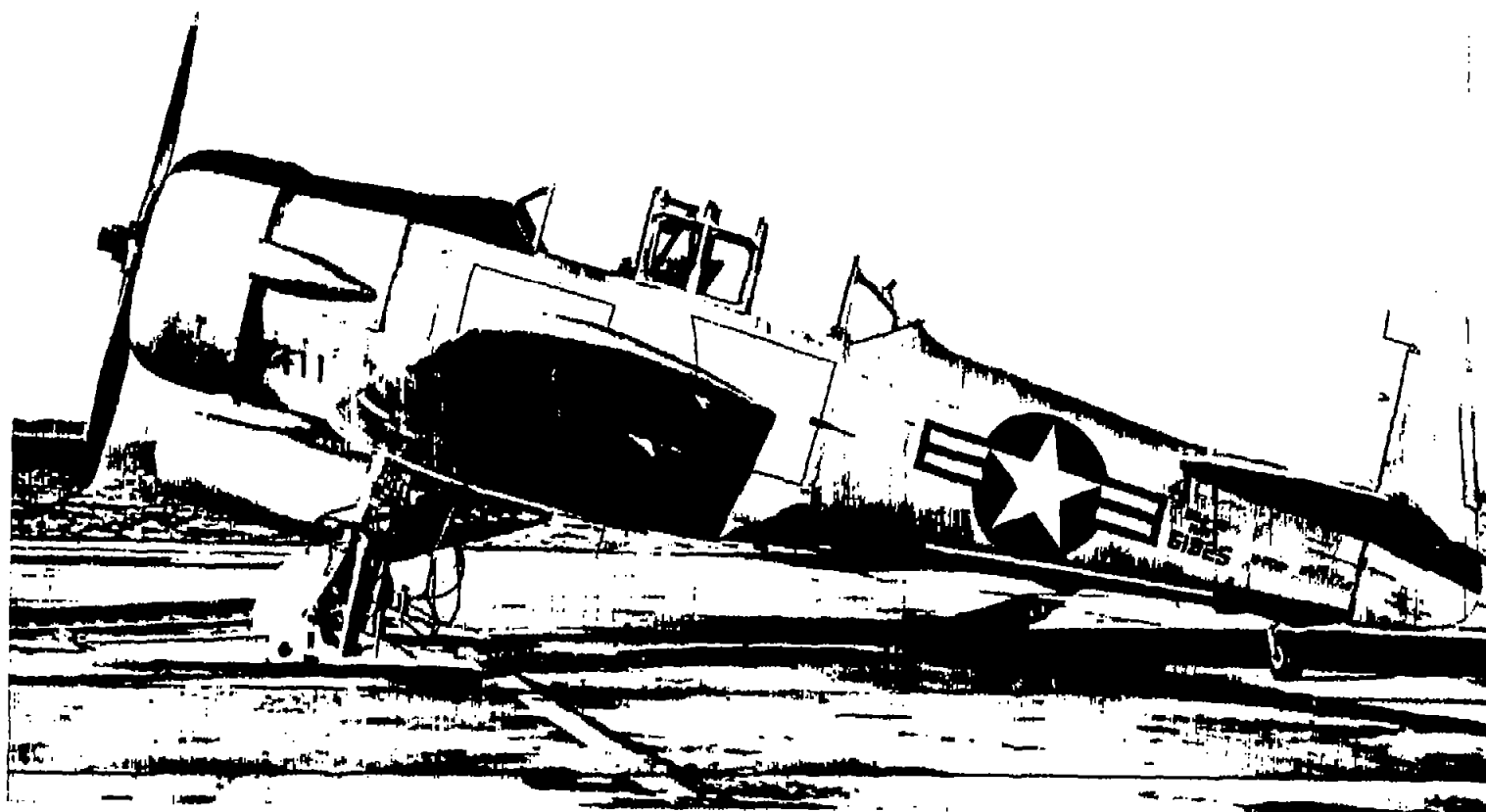
Figure 4.- Twin hydro-skis installed on a JRF-5 airplane (spray dams installed).



(a) Three-quarter front view.

L-87555

Figure 5.- SNJ-5C airplane equipped with flat-bottom skis and a wheel assembly.



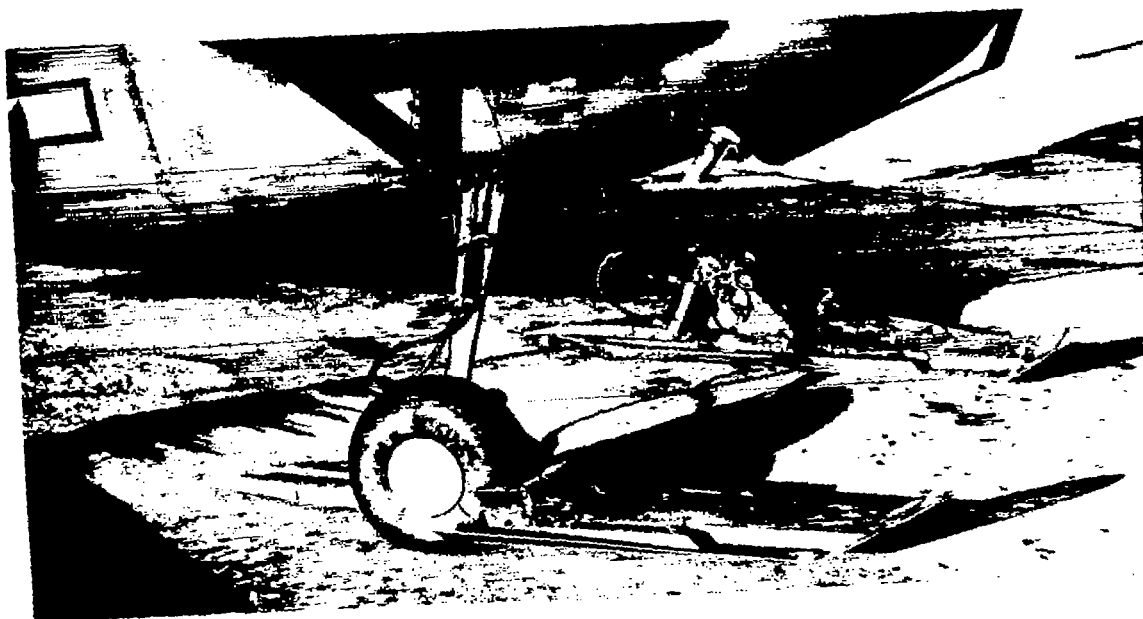
(b) Side view.

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Figure 5.- Concluded.



(a) Three-quarter rear view.



(b) Close-up view of skis.

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Figure 6.- Ski assembly on an OE-1 airplane.

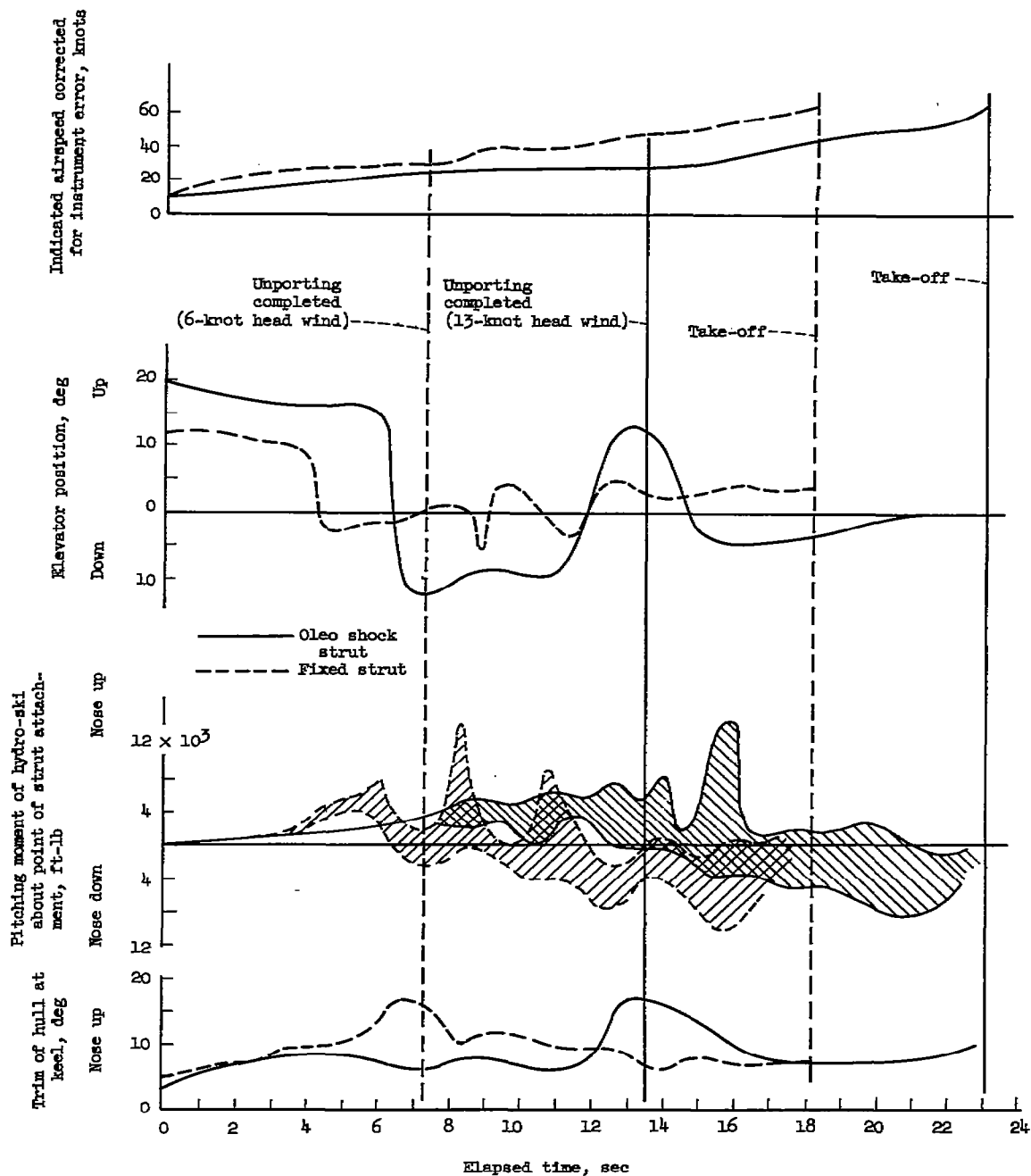


Figure 7.- Take-off records with a single hydro-ski on a JRF-5 airplane. Gross weight approximately 8,500 pounds; hydrodynamic trim flap closed; center of gravity at 23.6 percent mean aerodynamic chord.

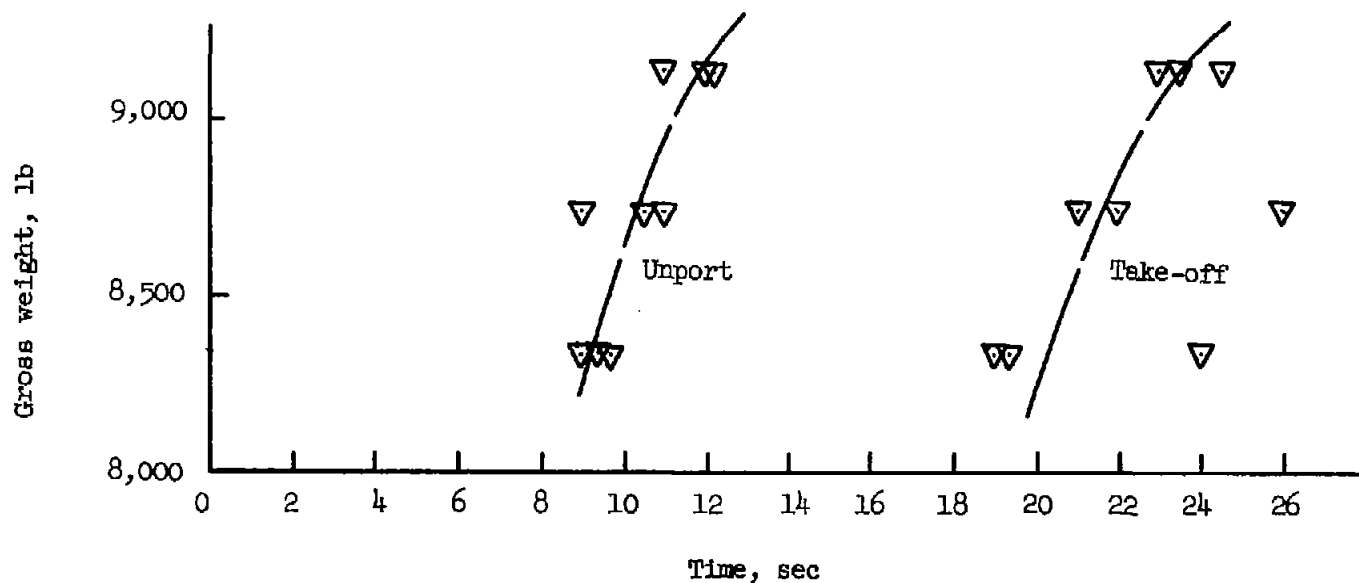


Figure 8.- Variation of unporting and take-off time with gross weight for JRF-5 airplane with single hydro-ski mounted on rigid strut. Hydrodynamic trim flap open 12.5° ; center of gravity at 22 percent mean aerodynamic chord.

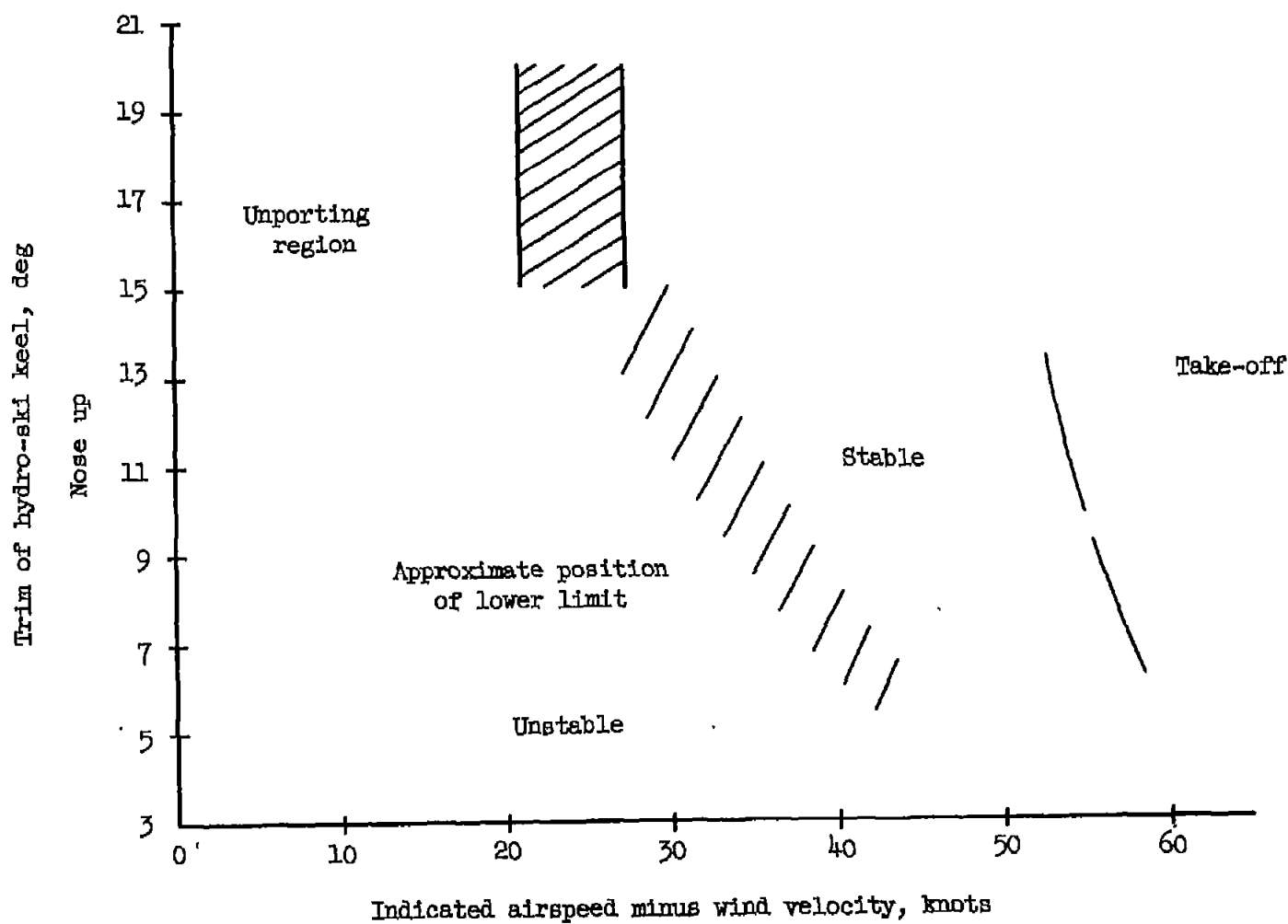
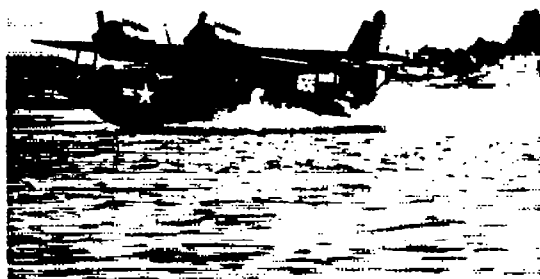


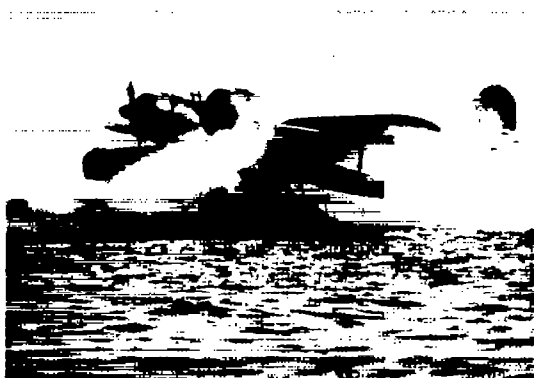
Figure 9.- Approximate trim limits of hydrodynamic stability of JRF-5 airplane with a single hydro-ski (upper limit not determined).



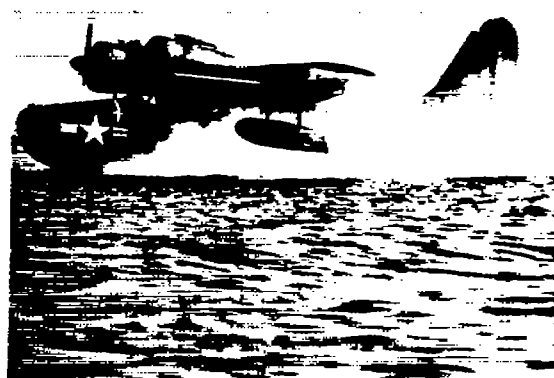
(a)



(b)



(c)



(d)

Figure 10.- Unporting of JRF-5 airplane with twin hydro-skis. L-87558



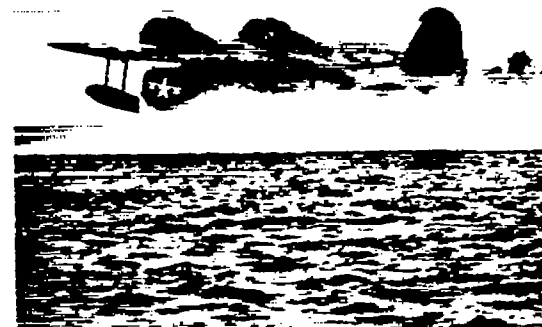
(e)



(f)



(g)



(h)

Figure 10.- Concluded.

L-87559

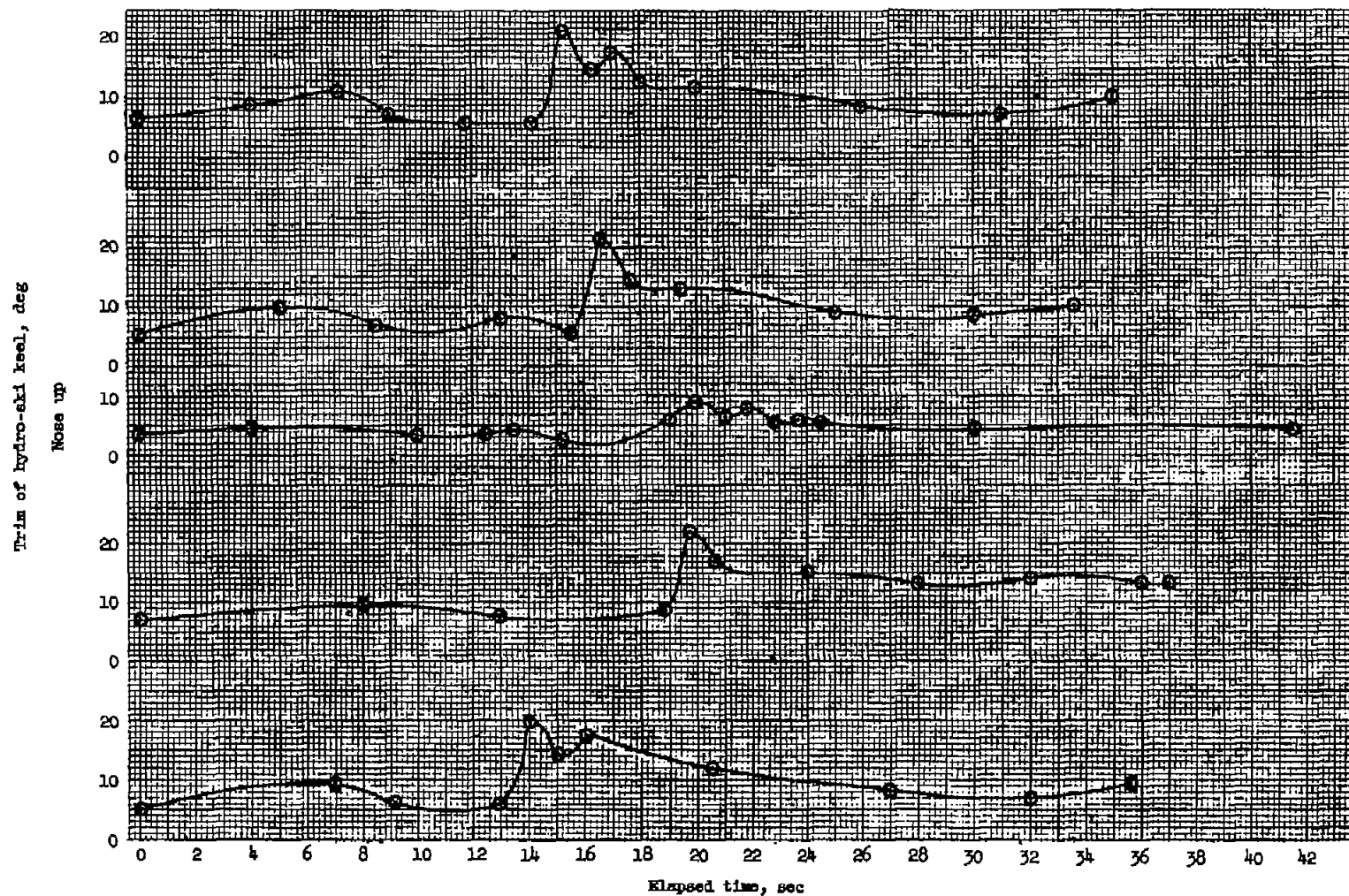


Figure 11.- Time history of trim for five take-offs with a JRF-5 airplane with twin hydro-skis.

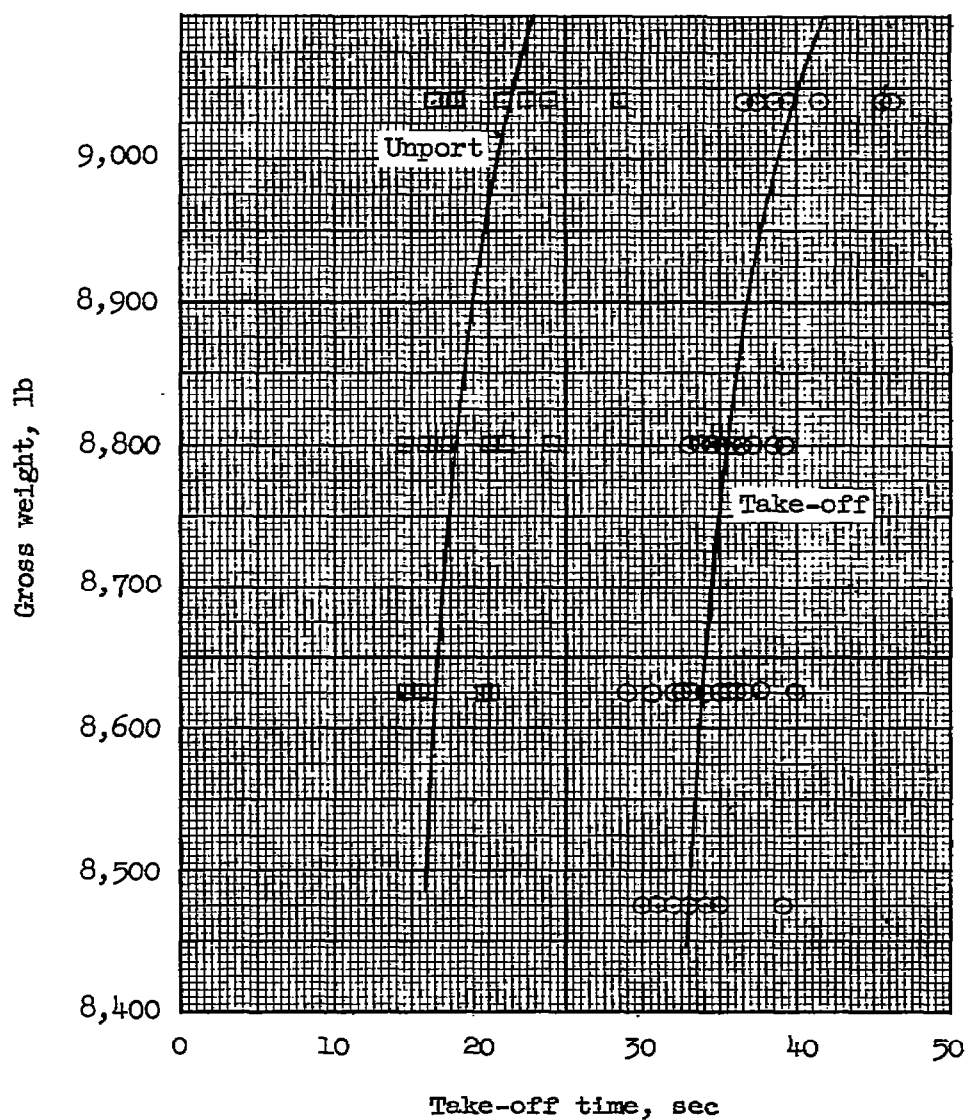
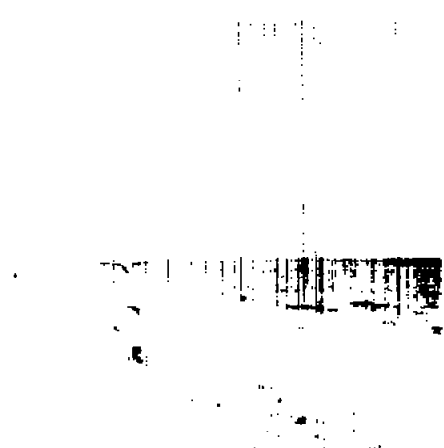



Figure 12.- Variation of unporting and take-off time with gross weight for JRF-5 airplane with twin hydro-skis.




(a) Approach.



(b) Transition.



(c) Run-out.



(d) Stopped. L-87560

Figure 13.- Water-to-beach landing of OE-1 airplane equipped with skis.

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